Fabrication of SPR chip with multiple air-gaps using SoQ bonding

Yeonsu Lee[a], Sung-min Sim[a], Hye-Lim Kang[a], Eduardo Fontana[b], Ignacio Llamas-Garro[c], Gustavo Olivera Cavalcanti[d], Jung-Mu Kim[a*]

[a] Chonbuk National University, Jeonju, 561-756, Republic of Korea
[b] Universidade Federal de Pernambuco, Recife, 50740-550, Brazil
[c] Centre Tecnològic de Telecomunicacions de Catalunya, Castelldefels 08860, Barcelona, Spain
[d] Universidade de Pernambuco, Recife, 50720-001, Brazil
e-mail: jungmukim@jbnu.ac.kr

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Abstract

SPR effect has been used in a number of applications such as biosensors and food safety sensors [1-2]. In the Otto configuration based SPR chip, a negative effect of the adhesion layer on the SPR quality can be eliminated because of the arrangement of the metal film which is separated from the glass substrate and this characteristic was analyzed a previous study [3]. It is widely known that the air-gap distance of the SPR chip is a very important factor for attaining high sensitivity. In an accurately designed SPR chip, the resonance angle of the SPR curve is shifted perceptively when the target molecule is detected. Thus, if the SPR chip has multiple air-gap distances, multiple SPR effects can be used to detect various target molecules by using a single SPR chip.

In this study, an Otto configuration based SPR chip with multiple air-gaps for real-time multiple SPR sensing is proposed and fabricated using the silicon on quartz (SoQ) bonding process. The multiple SPR effect of the proposed SPR chip is analyzed by using FEM simulation.

A schematic view of the proposed SPR chip is shown in Fig. 1. The whole size of the proposed SPR chip is $114 \times 114 \times 1\ \mathrm{mm}^3$. The proposed SPR chip consists of a glass substrate and a silicon substrate with multiple air-gaps (d_g = 1.8 μm, 2.3 μm, 2.8 μm and 3.2 μm) where a 200 nm-thick gold is used as a metal film. For gas detection or biosensing which will be conducted as a further study, the inlet and outlet diameters for tubing liquid or gas are designed to be 1.8 mm. Fig. 2 shows the simulated SPR curve using FEM simulation (COMSOL Multiphysics®) based on the design parameters at a wavelength of 975.1 nm. In this simulation result, reflectance values at the resonance angle are 0.094 at 42.15°, 0.492 at 42.18°, 0.775 at 40.26° and 0.727 at 40.65°, respectively, according to the four different air-gap distances. Fig. 3 shows the mathematically calculated minimum reflectance when the wavelength of the incident laser is varied from 500 nm to 2700 nm. Out of this result, we expect that the proposed SPR chip can be used in a multiple SPR sensing system by using appropriate laser sources.

The proposed Otto configuration based SPR chip is fabricated using a SoQ bonding process. First, a 2 μm-deep initial cavity is machined on a 500 μm-thick Silicon substrate using a deep reactive ion etching (DRIE) process. After the initial cavity generation, the multistep is generated with a step size of 0.5 μm by using additional deep reactive ion etching process. Through holes for inlet and outlet are also generated on the silicon substrate by using DRIE process. Then, the 200 nm-thick Au layer is deposited with a 10 nm-thick Cr layer on the silicon cavity, by using the lift-off process. The micromachined silicon substrate and the 500 μm-thick quartz wafer are manually bonded. Finally, the manually bonded wafers are annealed in a furnace under the proper condition (temperature of 200 °C) for 2 hours. Fig. 4 shows the measured profile of the generated multistep on the silicon substrate.

In this study, the Otto configuration based SPR chip with multiple air-gaps was designed and fabricated. The FEM simulation results of the SPR effect based on the design parameters agree well with the mathematically calculated results. We expect that the proposed Otto configuration based SPR chip with multiple air-gaps will be effectively used for real-time multiple gas detection or biosensing system.

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Reference

[1] J. Homola, "Present and future of surface plasmon resonance biosensors," Analytical and Bioanalytical Chemistry, Vol. 377, 2003, pp. 528-539.

[2] M. Piliarik, L. Pàrovà, J. Homola "High-throughput SPR sensros for food safety," Biosensors and Bioelectronics, Vol. 24, 2009, pp. 1399-1404.

[3] Y.S. Lee, S. M. Sim, E. Fontana, I. Llamas-Garro, G. O. Cavalcanti, J. M. Kim, SPR chip fabrication using silicon-on-quartz bonding, Proc. MNE 2015 Conf.

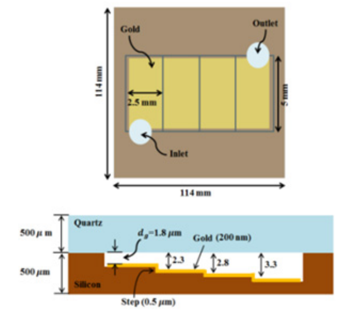

Figure 1. Schematic view of the proposed SPR chip

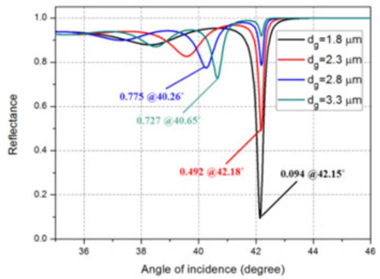

Figure 2. FEM simulation results of the SPR effect

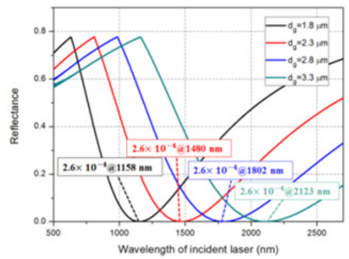

Figure 3. Calculated minimum reflectance according to the incident laser wavelength

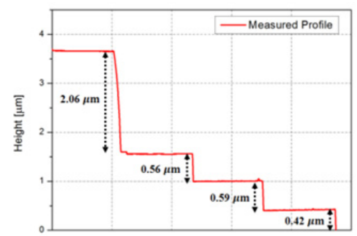

Figure 4. Measured profile of the generated multistep on the silicon substrate